

# Finding $H^0 \rightarrow b\bar{b}$ at the LHC

Moriond, 18. March 2001

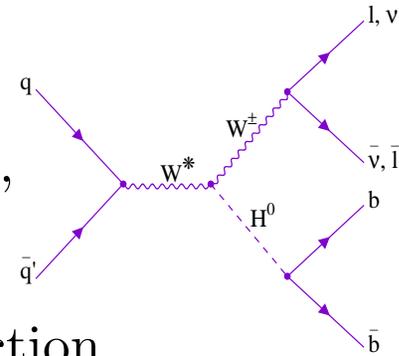
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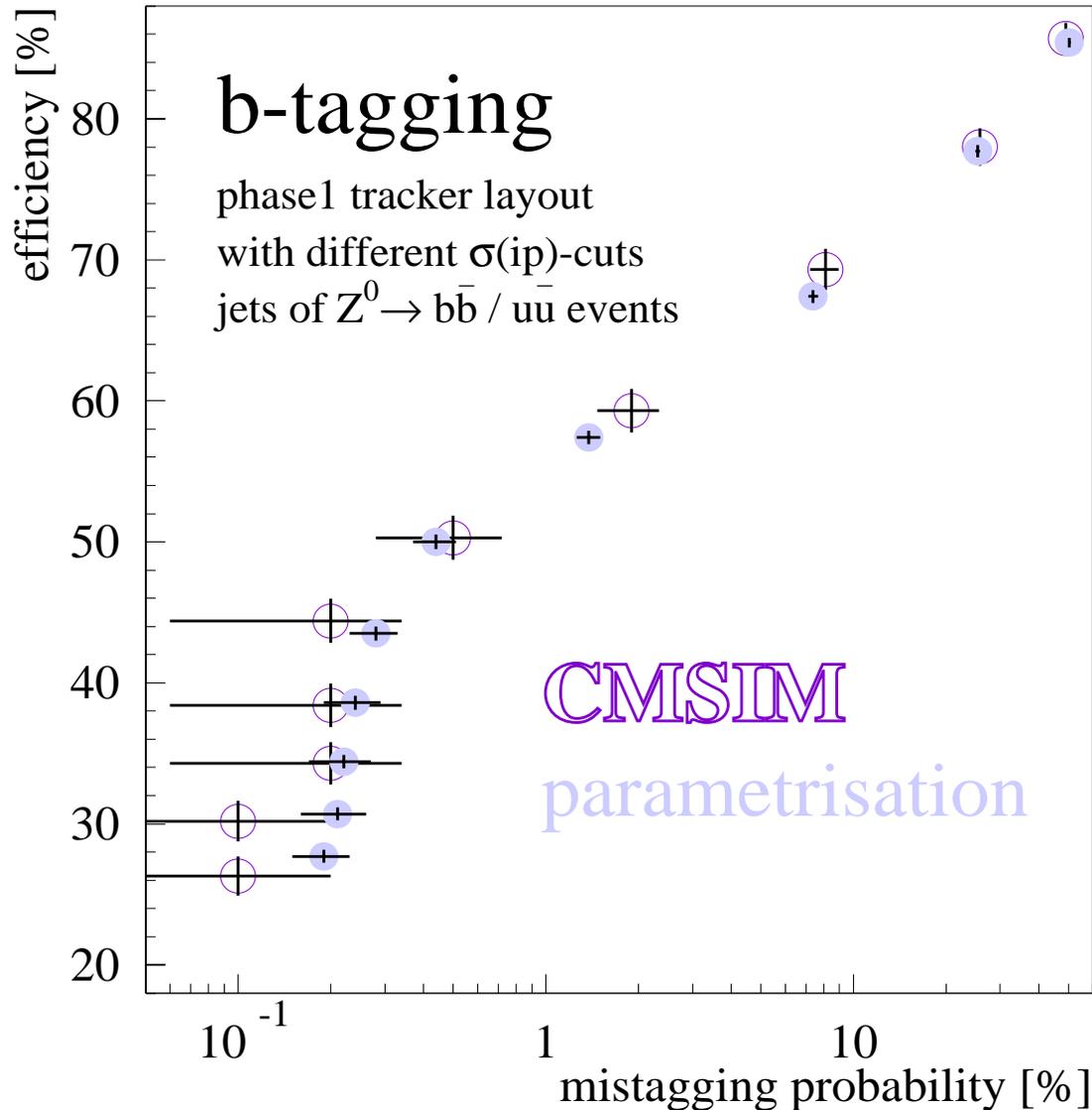
- Introduction
- $t\bar{t}H^0$ :
  - ◇ SM Higgs results
  - ◇ Yukawa coupling  $y_t$
  - ◇ MSSM Higgs results
- $W^\pm H^0$ :
  - ◇ SM Higgs results
  - ◇  $WWH$  coupling  $g_{WWH}$
  - ◇ MSSM Higgs results
- Conclusions

# General Situation

- ◇ final states contain jets leptons and  $E_T^{miss}$   
⇒ all detector components are needed
- ◇ BGs are  $\approx 100$  times larger than signal,  
but a large fraction is reducible
- ◇ excellent  $b$ -tagging ⇒ efficient BG rejection  
( $\epsilon_b \approx 60\%$  ,  $\epsilon_c \approx 10\%$  and  $\epsilon_q \approx 1\%$ )
- ◇ good jet reconstruction ⇒ good mass resolution  
(Higgs mass resolution of 10% to 15%)
- ◇ ATLAS and CMS fulfil these requirements



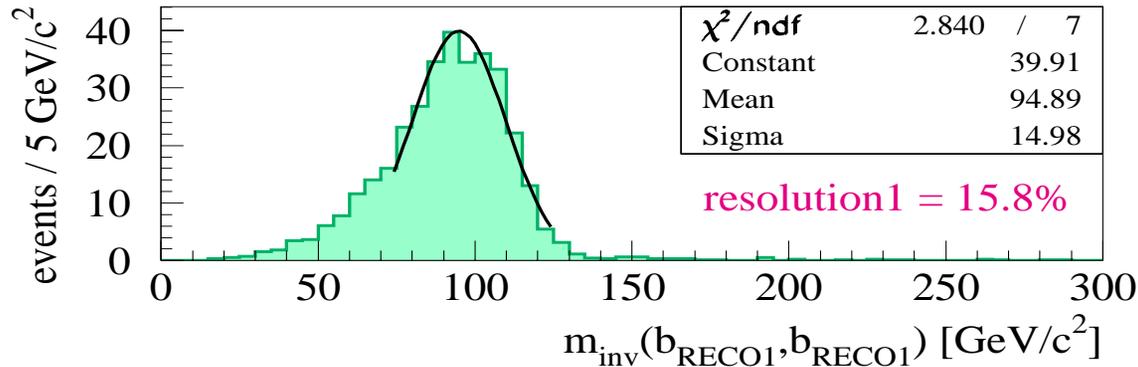
# FATSIM (++)



fast tracker simulation:

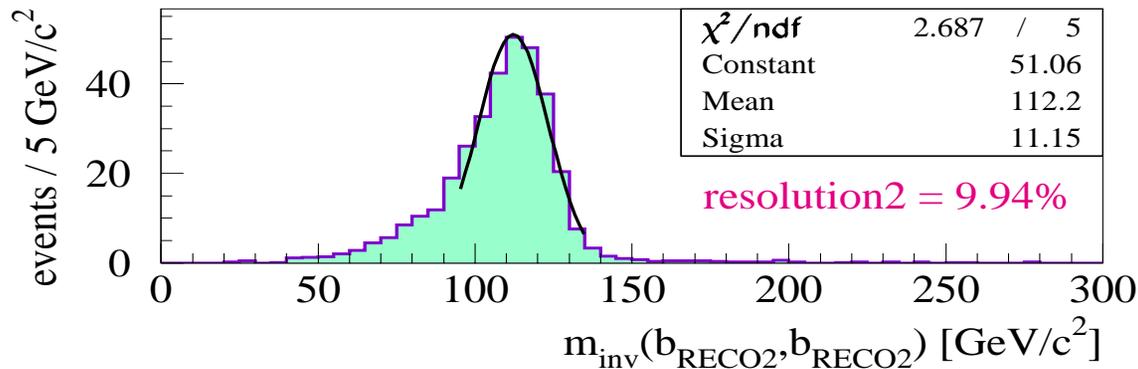
- ◇ parametrisation of TDR tracker response (phase I + phase II)
- ◇ 2 tracks per jet with min. 6 hits (2 pix.h.)  
 $p_T > 0.9 \text{ GeV}/c$   
transverse  $ip < 2 \text{ mm}$
- ◇  $b$ -tagging performance is in good agreement with CMSIM simulation and TDR results

# Higgs Mass Resolution



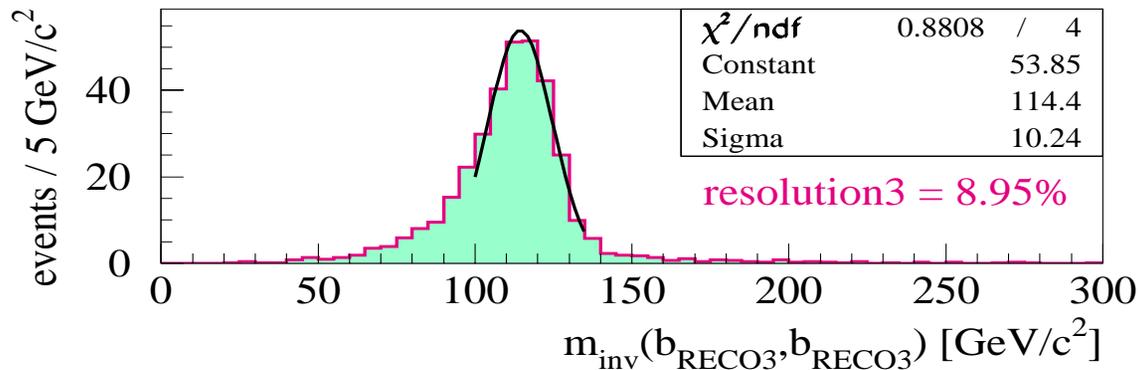
*RECO1:*

uncorrected j-j-mass  
from  $W^\pm H^0$  events



*RECO2:*

single jet energy  
corrections applied

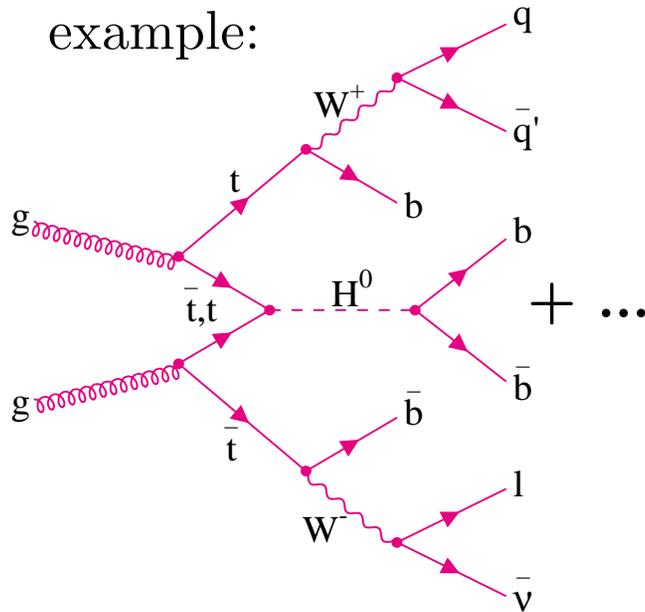


*RECO3:*

combination with  
additional FSR jets

# $t\bar{t}H^0$ Channel

example:



◇ cross sections:

$\sigma_{t\bar{t}H^0} \times BR_{H^0 \rightarrow b\bar{b}}$	=	0.78 - 0.32 pb
$m_{H^0}$	=	110 - 130 GeV/c <sup>2</sup>
<hr/>		
$\sigma_{t\bar{t}Z^0}$	=	0.65 pb
$\sigma_{t\bar{t}b\bar{b}}$	=	3.28 pb
$\sigma_{t\bar{t}jj}$	=	507 pb

⇒ get  $k_{t\bar{t}q\bar{q}} = 1.9$  , introduce  $k_{t\bar{t}H^0, t\bar{t}Z^0} = 1.5$

- ◇ generator for signal + BGs: CompHEP , fragmentation: PYTHIA
- ◇ detector simulation: fast CMS response simulation “CMSJET” with parametrisations based on detailed GEANT simulations
- ◇ trigger: 1 isol.  $e^\pm$  or  $\mu^\pm$  ( $p_T > 10$  GeV) and min. 6 jets ( $E_T > 20$  GeV)
- ◇ tag  $b$ -jets , reconstruct resonances (+ some kinematic cuts)  
maximum likelihood method is used for S / B optimisation
- ◇ mass window around the  $m_{inv.}(b, \bar{b})$  peak

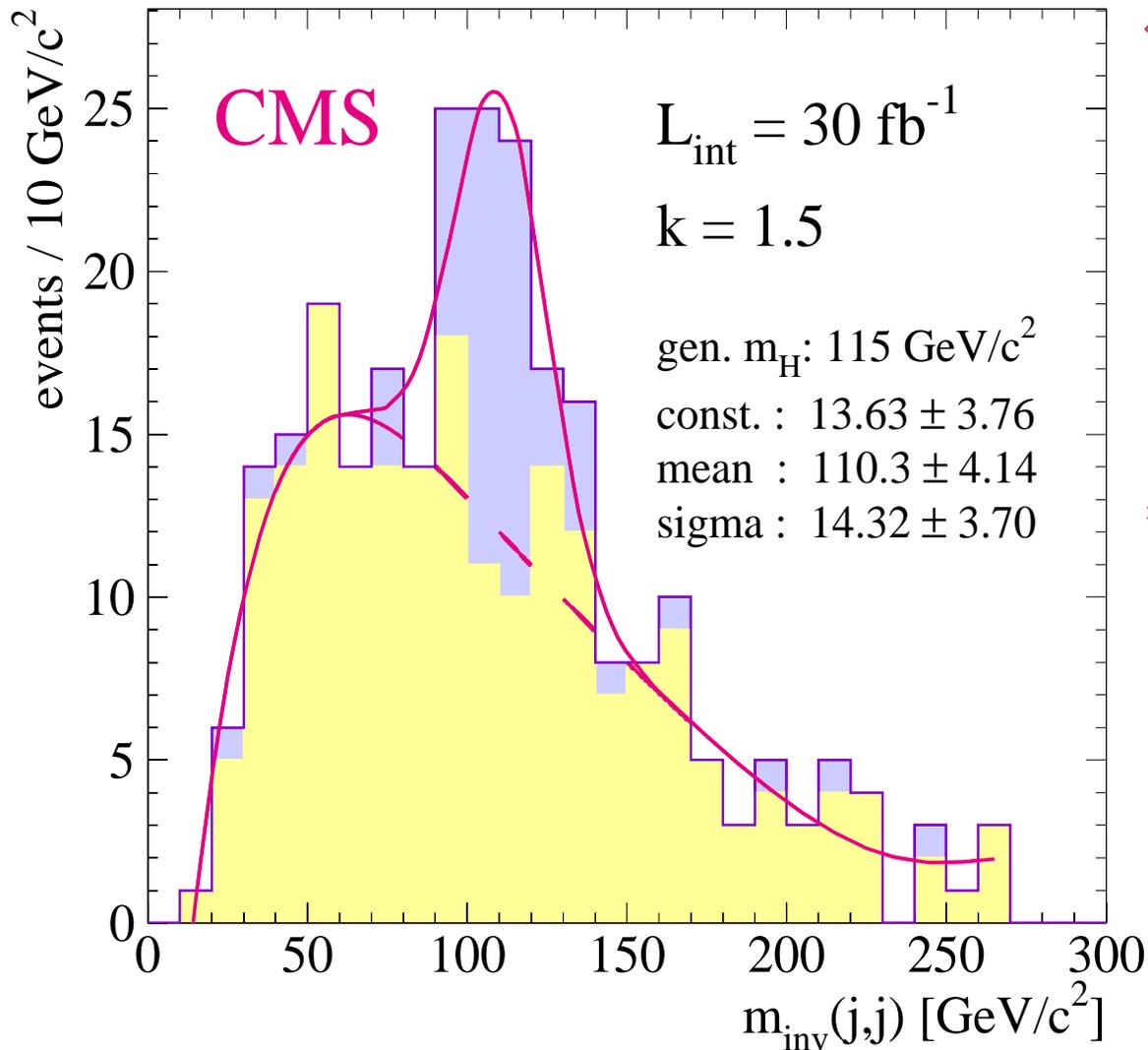
# Likelihood Function

$$\begin{aligned} \text{Event L.} &= b\text{-probability}[\sigma_{ip}(BH_1), E_T(BH_1)] \\ &\times b\text{-probability}[\sigma_{ip}(BH_2), E_T(BH_2)] \\ &\times b\text{-probability}[\sigma_{ip}(BT_L), E_T(BT_L)] \\ &\times b\text{-probability}[\sigma_{ip}(BT_H), E_T(BT_H)] \\ &\times 1 - b\text{-probability}[|\sigma_{ip}(JW_1)|, E_T(JW_1)] \\ &\times 1 - b\text{-probability}[|\sigma_{ip}(JW_2)|, E_T(JW_2)] \\ &\times \exp\left[-0.5 \times \left\{ \frac{m_{inv}(BT_L, l, \nu) - 169.6}{15.4} \right\}^2 \right] \\ &\times \exp\left[-0.5 \times \left\{ \frac{m_{inv}(JW_1, JW_2) - 80.3}{8.5} \right\}^2 \right] \\ &\times \exp\left[-0.5 \times \left\{ \frac{m_{inv}(BT_H, JW_1, JW_2) - 170.8}{11.1} \right\}^2 \right] \\ &\times f[E(BT_L) + E(BT_H) - E(BH_1) - E(BH_2)] \end{aligned}$$

**L\_BTAG** = lines 1-4 , **L\_RESO** = lines 7-9 , **L\_KINE** = ...  
...  $E_T$  balance, big total  $E_T$  and central jets

$$t\bar{t}H_{SM}^0 \rightarrow l^\pm \nu q\bar{q}b\bar{b}b\bar{b}$$

$$m_{H^0} = 115 \text{ GeV}/c^2$$



◇  $90 < m < 130 \text{ GeV}/c^2$ :

$N_{H115}$	=	38
$N_{t\bar{t}Z^0}$	=	3
$N_{t\bar{t}b\bar{b}}$	=	23
$N_{t\bar{t}jj}$	=	26
$N_{BG}$	=	52

⇒ results (stat.):

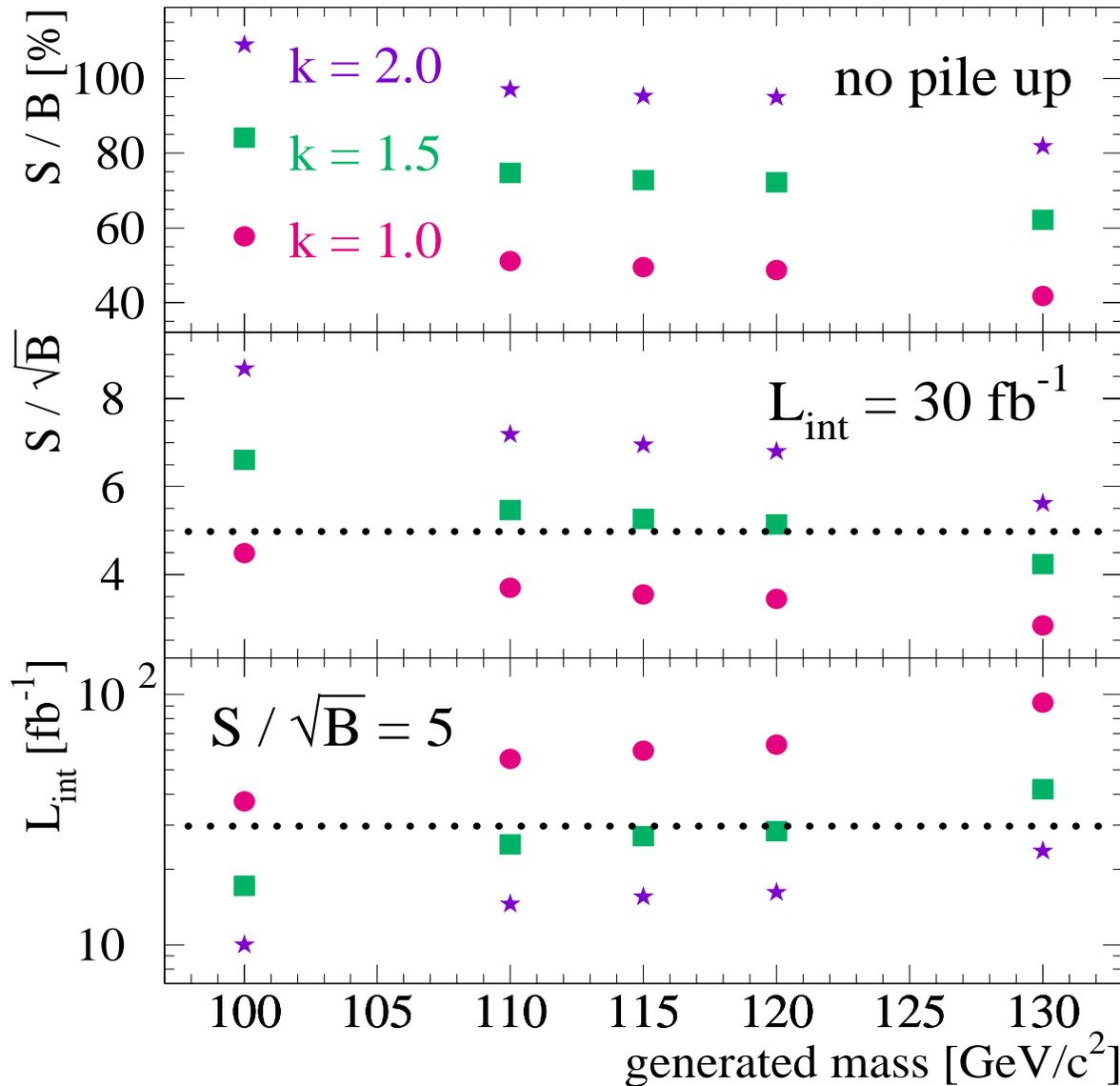
$$S/B = 73\%$$

$$S/\sqrt{B} = 5.3$$

$$\Delta y_t / y_t = 13\%$$

$$\Delta m / m = 3.8\%$$

# Sensitivities for $t\bar{t}H_{SM}^0 \rightarrow l^\pm \nu q\bar{q}b\bar{b}b\bar{b}$

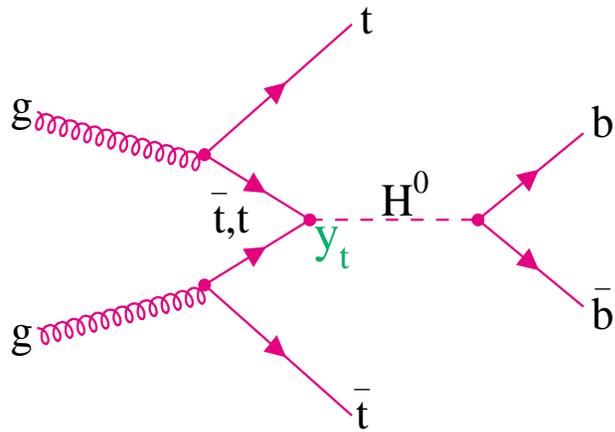


◇  $S/B$  is quite high - need no BG subtraction

◇  $S/\sqrt{B} = 5$  at 95/122/135  $\text{GeV}/c^2$

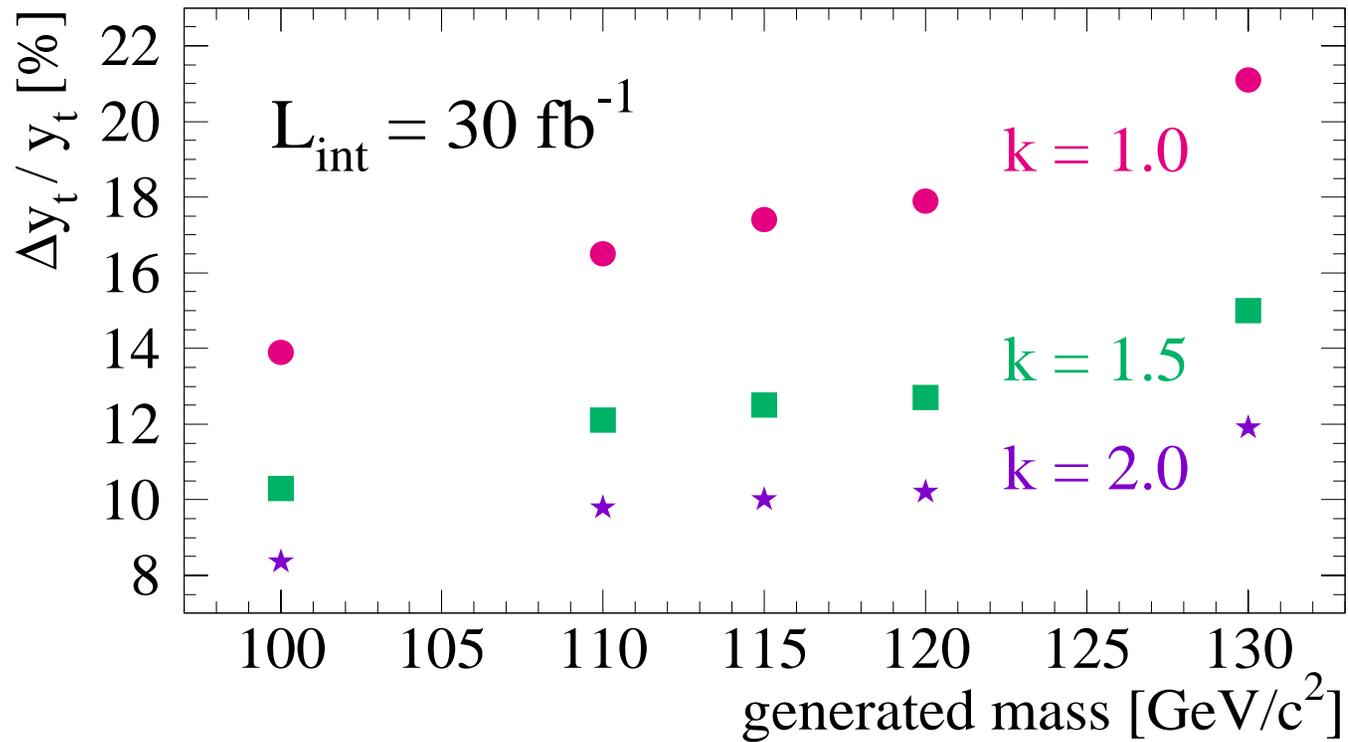
◇ visible signal already at low luminosity

# Top Higgs Yukawa Coupling

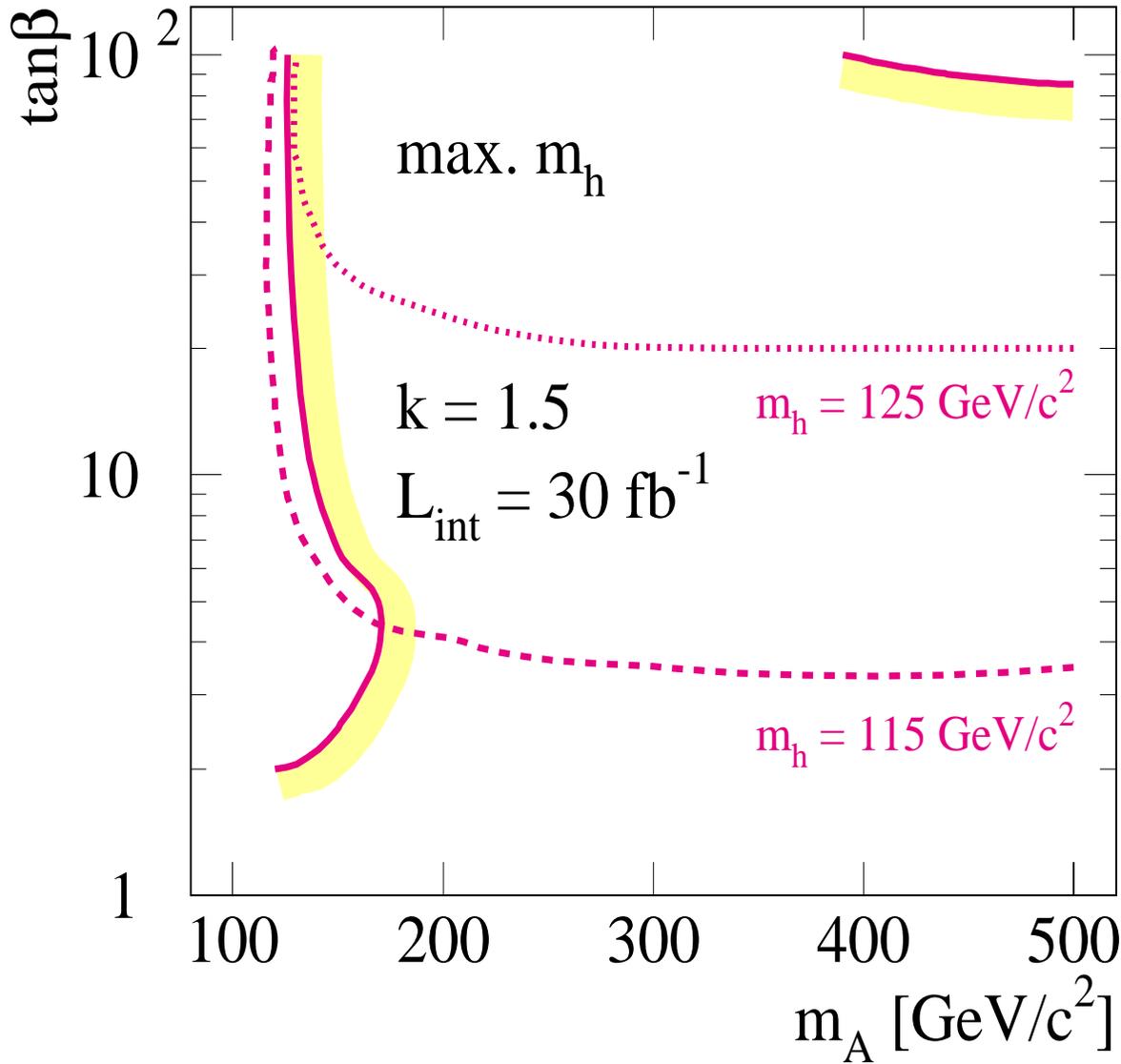


◇  $y_t \sim \sqrt{\sigma} \sim \sqrt{N}$

◇ assume known coupling to  $b\bar{b}$



# MSSM Coverage: $t\bar{t}h^0 \rightarrow l^\pm \nu q\bar{q}b\bar{b}b\bar{b}$



most unfavourable case  
for  $h^0 \rightarrow b\bar{b}$  is ...

- ◇ max.  $m_h$  scenario:
  - $M_{SUSY} = 1 \text{ TeV}$ ,
  - $\mu = -0.2 \text{ TeV}$ ,
  - $M_2 = 0.2 \text{ TeV}$ ,
  - $M_{\tilde{g}} = 0.8 M_{SUSY}$ ,
  - $X_t^{OS} = 2 M_{SUSY}$ ,
  - $X_t^{\overline{MS}} = \sqrt{6} M_{SUSY}$ ,
  - $A_b = A_t$

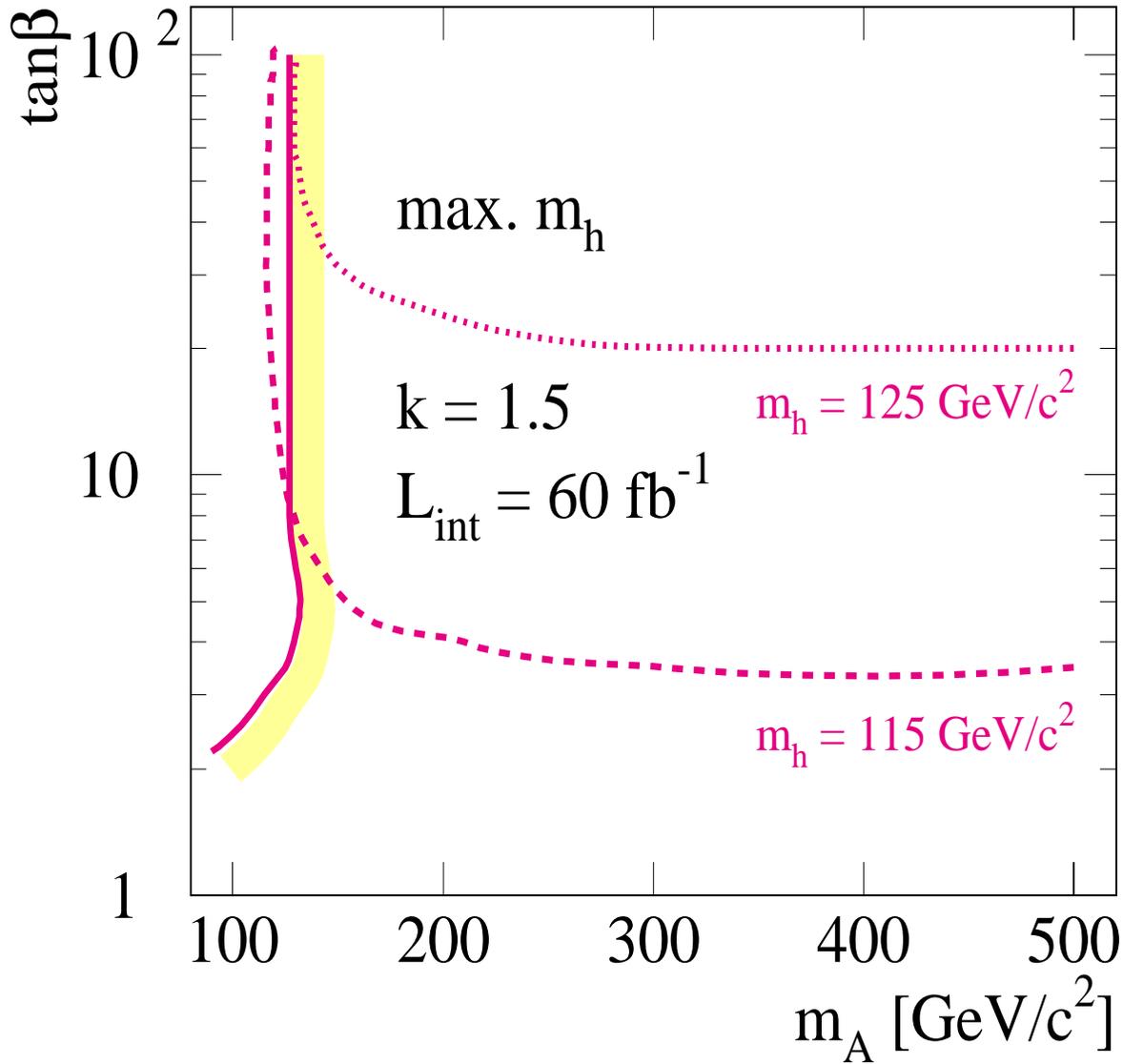
suggested by

M. Carena et al.

hep-ph/9912223

- ◇ no mixing scenario:  $m_h \leq 115 \text{ GeV}/c^2$  is fully contained in accessible area

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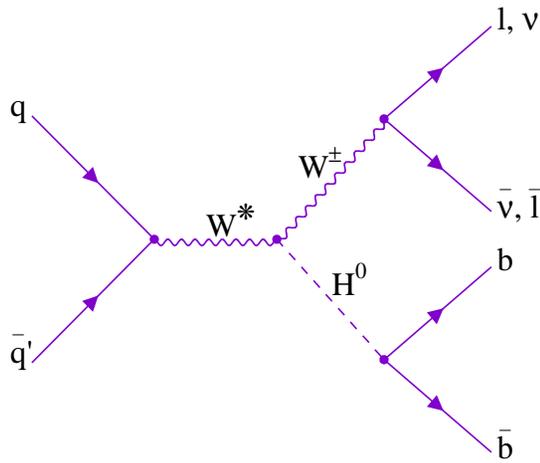
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# $W^\pm H^0$ Channel



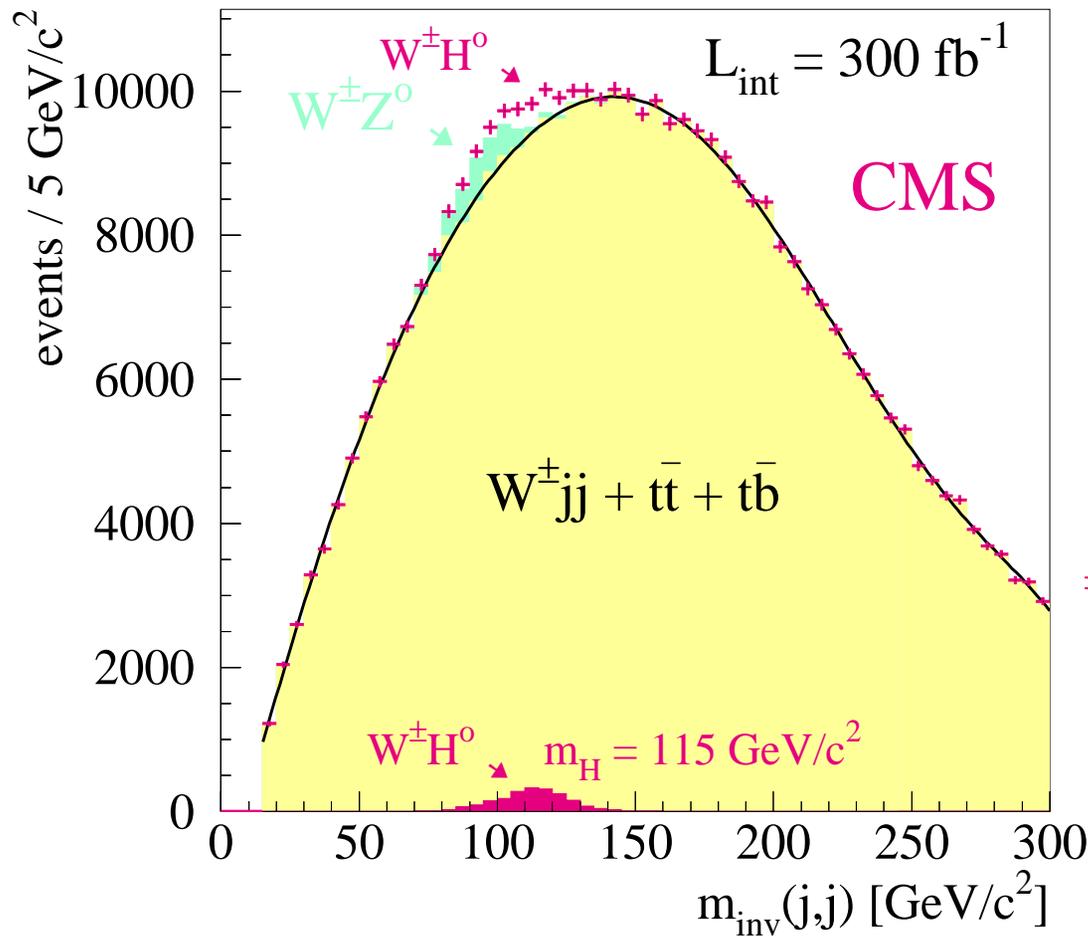
◇ cross sections:

$\sigma_{W^\pm H^0} \times BR_{H^0 \rightarrow b\bar{b}}$	=	1.28 - 0.54 pb
$m_{H^0}$	=	110 - 130 GeV/c <sup>2</sup>
$\sigma_{W^\pm Z^0}$	=	18.2 pb
$\sigma_{W^\pm jj}$	=	27.1 nb
$\sigma_{t\bar{t}}$	=	569 pb
$\sigma_{t\bar{b}}$	=	318 pb

- ◇ event generator + fragmentation: PYTHIA (for S + B)
- ◇ observation only at high luminosity  $\Rightarrow$  pile up is included
- ◇ detector simulation: fast CMS response simulation “CMSJET”
- ◇ trigger: 1 isol.  $e^\pm$  or  $\mu^\pm$  ( $p_T > 20$  GeV) and 2 jets ( $E_T > 30$  GeV)
- ◇ 2 tagged jets , jet veto , reconstruct  $m_T(W^\pm)$  ,  $E_T$  balance  
signal to background ratio analysed with cut method
- ◇ mass window around the  $m_{inv.}(b, \bar{b})$  peak

$$W^{\pm} H_{SM}^0 \rightarrow l^{\pm} \nu b \bar{b}$$

$$m_{H^0} = 115 \text{ GeV}/c^2$$



◇  $97 < m < 130 \text{ GeV}/c^2$ :

$N_{H115}$	=	1610
$N_{W^{\pm} Z^0}$	=	1198
$N_{W^{\pm} jj}$	=	27565
$N_{t\bar{t}}$	=	36089
$N_{t\bar{b}}$	=	6096
$N_{BG}$	=	70948

⇒ results (stat.):

$$S/B = 2.3\%$$

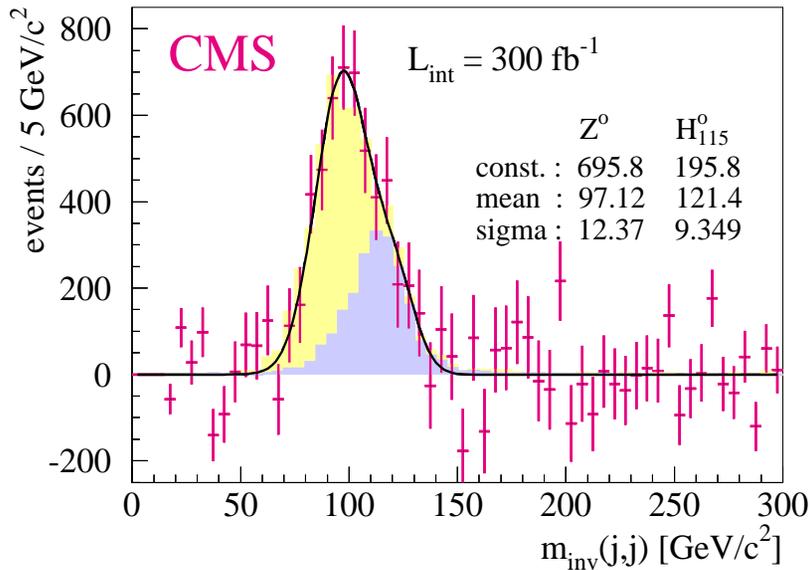
$$S/\sqrt{B} = 6.0$$

$$\frac{\Delta g_{WWH}}{g_{WWH}} = 8.4\%$$

$$\Delta m/m = 2.3\%$$

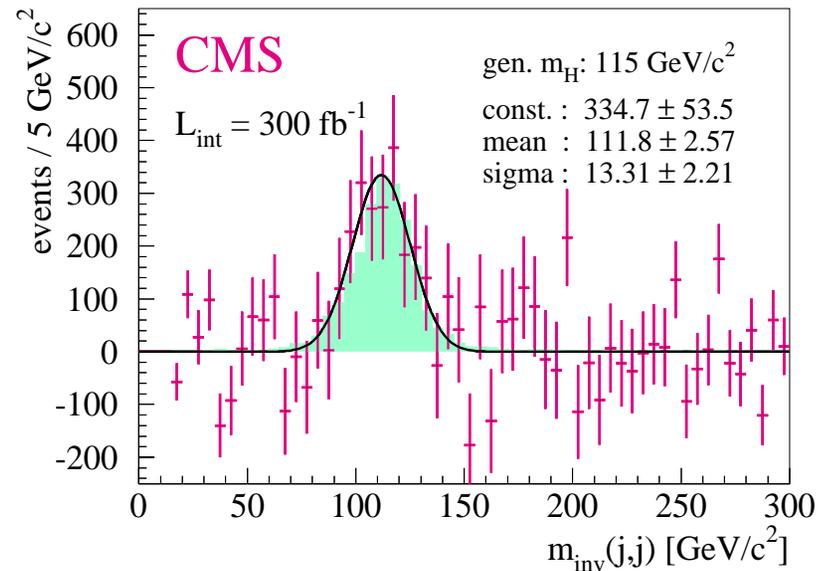
◇ signal over background is low ⇒ need to subtract the background

# Background Subtraction

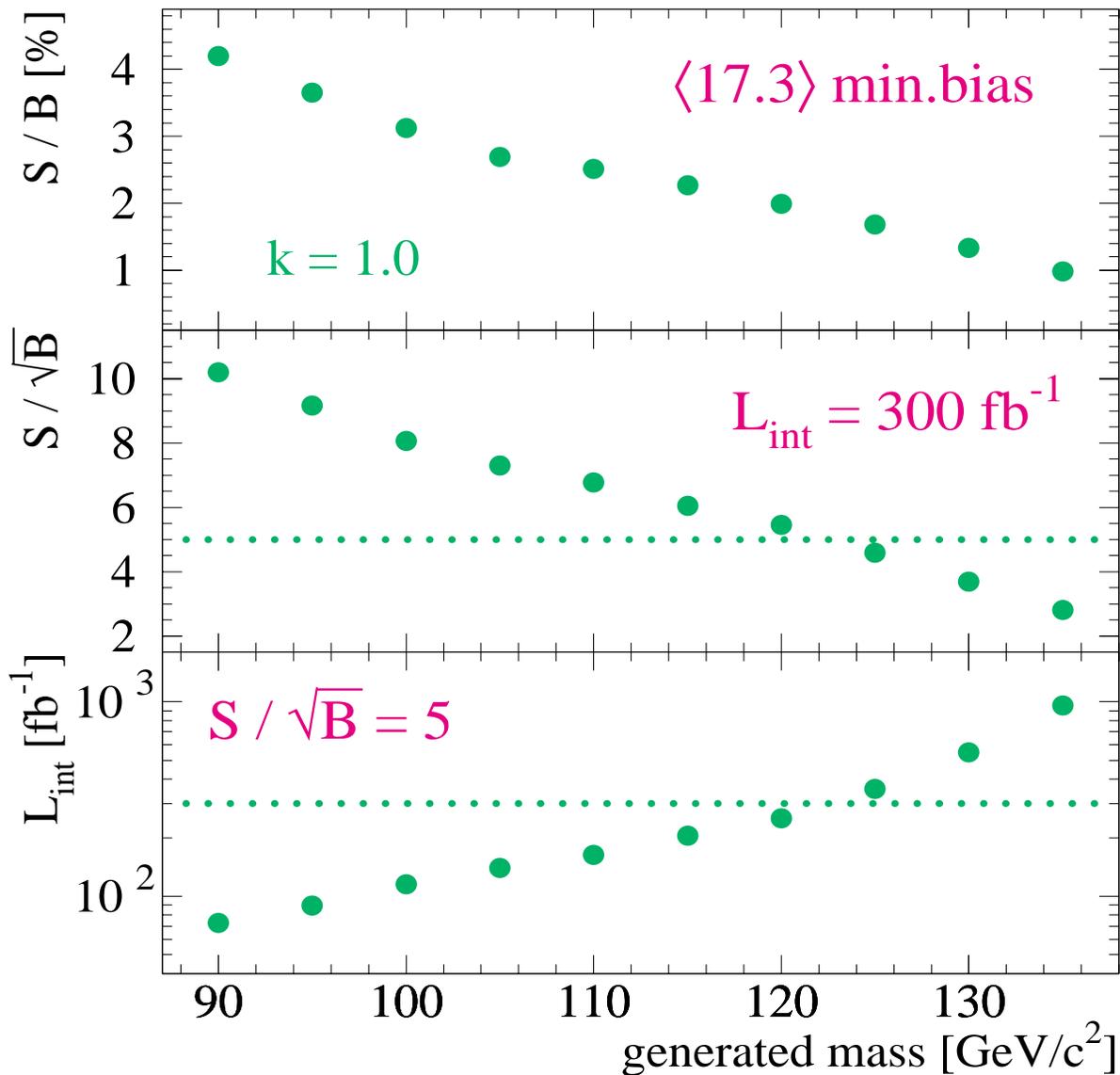


- ◇ generated  $m_{H^0} = 115 \text{ GeV}/c^2$
- ◇ all ev. minus non res. BG:  
double peak structure is visible  
each single peak is unprecise
- ◇ subtract also  $W^\pm Z^0$  peak

- ◇ all ev. minus all BG:  
fitted peak is practically ...  
... identical with gen. peak
- ◇ fitted  $\Delta m/m = 2.3\%$  (stat.)  
(expec.  $m_{H^0} = 113.5 \text{ GeV}/c^2$ )

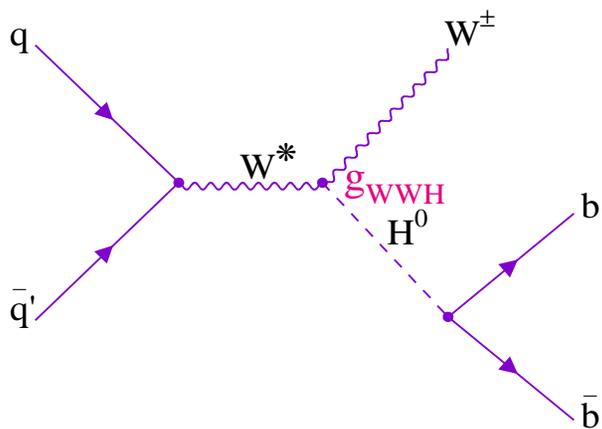


# Sensitivity for $W^\pm H_{SM}^0 \rightarrow l^\pm \nu b\bar{b}$



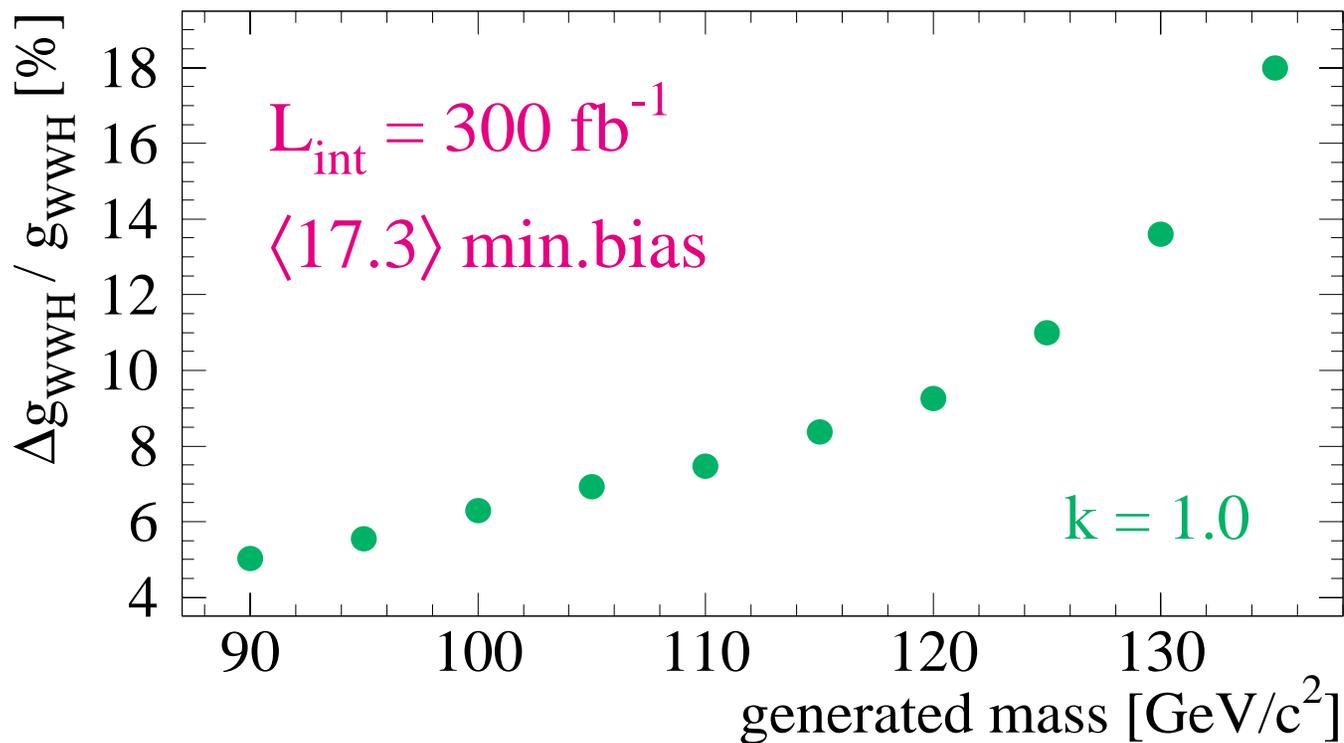
- ◇  $S/B$  is low and decreases with increasing  $m_{H^0}$
- ◇  $S/\sqrt{B} \geq 5$  for  $m_{H^0} \leq 123 \text{ GeV}/c^2$  and  $L_{int} = 300 \text{ fb}^{-1}$

# WWH Coupling

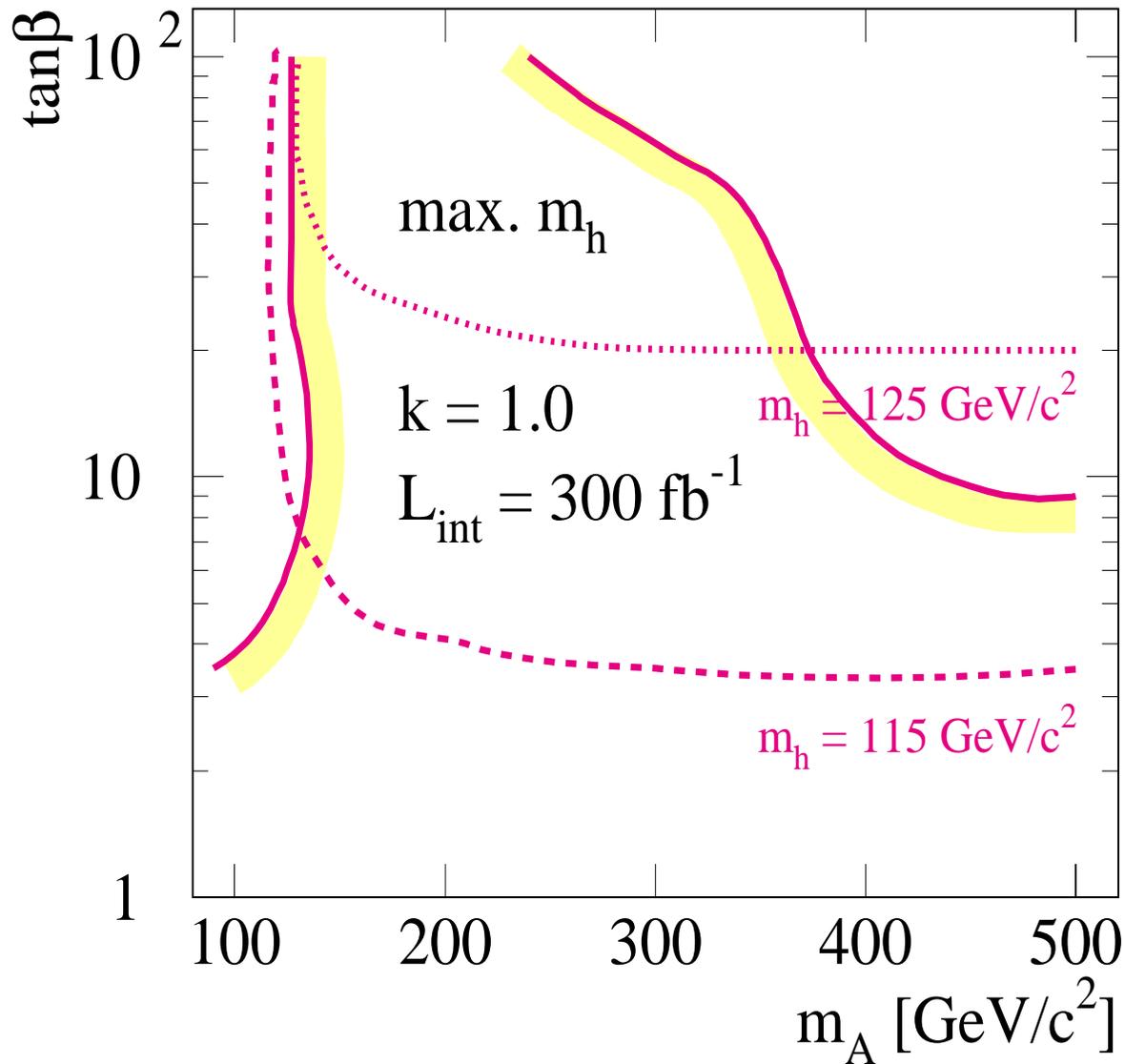


◇  $g_{WWH} \sim \sqrt{\sigma} \sim \sqrt{N}$

◇ assume known coupling to  $b\bar{b}$



# MSSM Coverage: $W^\pm h^0 \rightarrow l^\pm \nu b \bar{b}$



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- ◇ no mixing scenario:  $m_h \leq 115 \text{ GeV}/c^2$  is fully contained in accessible area

# Conclusions

- ◇  $t\bar{t}H_{SM}^0$  is potentially a discovery channel
- ◇ most of the MSSM parameter space can be covered with  $t\bar{t}h^0$ ,  $h^0 \rightarrow b\bar{b}$
- ◇ under good conditions ATLAS + CMS can discover a Higgs boson ( $\leq 120$  GeV) in the first year of LHC
- ◇  $W^\pm H_{SM}^0$  is not a discovery channel, but allows to measure  $WWH$  coupling